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Application of unglazed PVT collectors for domestic hot water pre-heating in a development and testing system

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Abstract

PVT collectors are solar thermal collectors which have an absorber made from solar cells. They provide heat and electricity simultaneously. PVT-collectors may be glazed flat-plate collectors (i.e. the collector uses a PVT absorber, heat insulation on its rear side and an additional glass cover above the PVT-absorber) or unglazed collectors (which is essentially a PV-panel with a heat exchanger plate on its rear side.) We report on a demonstration system set up at the test field of SPF, Institute for Solar Technology, at the University of Applied Sciences Rapperswil in Switzerland. The system is dimensioned in such a way that especially the performance of large uncovered PVT-collector systems for example on the roofs of multi-family houses for the pre-heating of domestic hot water can be investigated.

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Keywords: PVT-collectors; PVT systems; pre-heating of domestic hot water.

1. Introduction: pros and cons on PVT

PVT is not a new idea; it rather is a topic since PV modules and solar thermal collectors exist. Among many others, some of the work on the development of PVT collectors was for example carried out by a group at ECN [1], by Rockendorf et al. from ISFH [2], by Dupeyrat and Rommel at Fraunhofer ISE [3], and by Bertram et al. at ISFH [4].

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Still PVT is often discussed as a controversial topic. The three main arguments against it are:

1. Solar thermal applications would always need high temperatures which causes high solar cell temperatures which in a consequence cause lower electrical efficiency due to the negative temperature coefficient of solar cells.

2. It is better and much easier if PV and solar thermal are treated in separate systems because water and electricity too near together would cause technical problems.

3. PV-panels and solar collectors installed as side-by-sides systems would always be cheaper than PVT systems.

The arguments to these three points in favor of PVT are:

1. It depends on the operating conditions imposed by the thermal system on the PVT collector if on the average the cell temperature is higher than in a PV-alone-application or not. In many cases, for example in pre-heating systems for domestic hot water, the operating temperature of an uncovered PVT collector is lower than for pure PV system. This depends strongly on the dimensioning of the system and the solar fraction aimed at.

2. There is no doubt that PVT collectors (uncovered and covered) can be developed to solve all technical and developmental challenges. But development work is necessary to eliminate possible problems.

3. Side-by-side installations are only more cost-effective until a good PVT-technology is developed. Of course, it is a challenge that the development of a new PVT-technology has always to compete against the cost reduction potential of the two already well-developed technologies and the market forces of PV and solar thermal.

In our opinion the most important argument in the long run is the fact that PVT enables a higher energetic and exergetic efficiency for the conversion of solar radiation compared to side-by-side installations. We do not expect that PVT-systems will neither completely replace PV-installations nor solar thermal collector systems, but we are convinced that covered and uncovered PVT collectors will play a role in specific applications and that they will have their market share in the future.

Of course, in the present development phase of PVT it is necessary to concentrate on applications in which the advantages of PVT are obvious and can be demonstrated most easily. We therefore investigate at SPF, the Institute for Solar Technology of the University of Applied Sciences in Rapperswil, Switzerland, the application of uncovered PVT-collectors in large systems on the roofs of multi-family houses for pre-heating of domestic hot water.

2. Demonstration system for pre-heating of domestic hot water with uncovered PVT-collectors

Figure 1 shows the system installed and its components. The industry partner in this Swiss-funded CTI-project is the company Meyer Burger. The six PVT collectors [5] are connected in parallel and installed on a test-roof at an angle of 45° with South-orientation. Two PV-modules [6] with the identical module construction as used in the PVT-collectors are installed to the left for comparison reasons. Each single module and PVT-collector is connected to its own inverter. The PVT collector field is connected to a solar water storage tank of 500 litres volume using an immersed heat exchanger. Every day 600 litres are drawn from the storage tank. The draw profile was generated based on the simulation of the draw pattern in multi-family-houses, using the software DHW-calc. The draws are taken hourly with a rate of about 450 l/h.

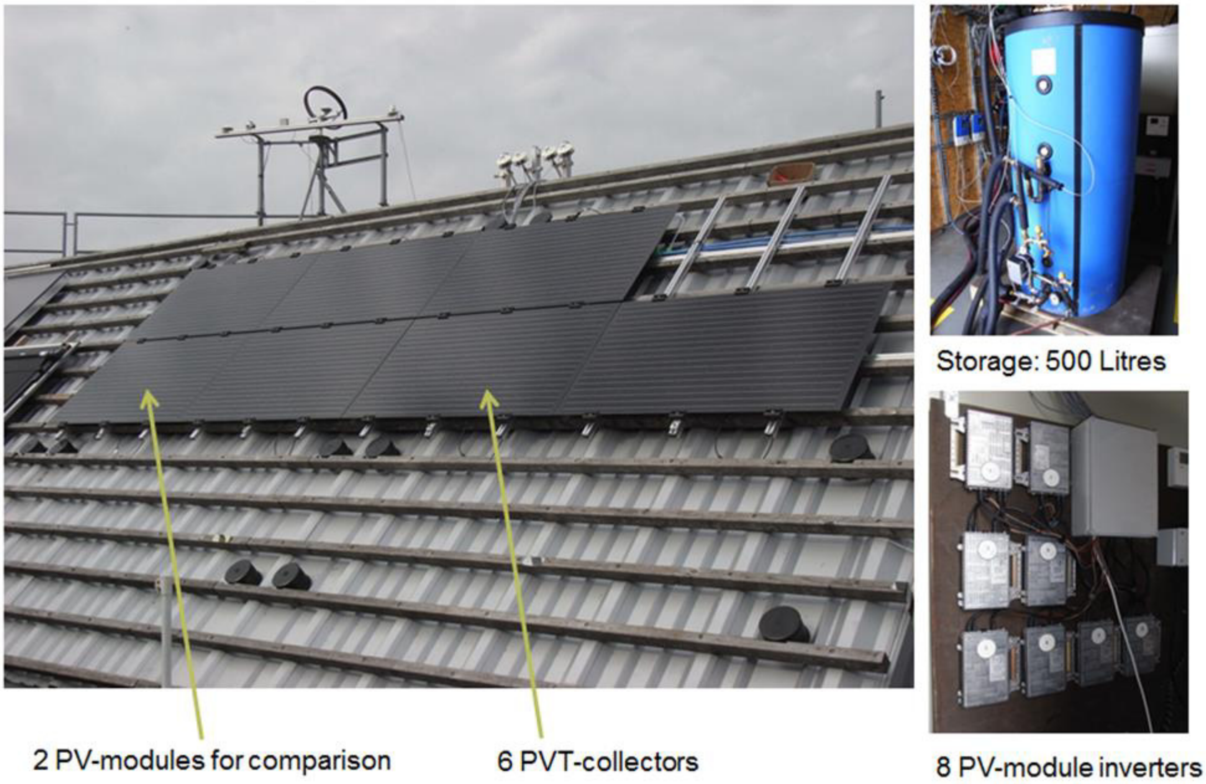

Fig. 1. The left picture shows the field of two PV-modules and the PVT-collector field during installation with five of the six collectors installed. The PVT collector field has an aperture area of 6*1.656 m * 0.991 m = 9.85 m^2. Tt is connected to a 500 l solar thermal storage tank. Each of the PV and PVT devices is electrically connected to its own inverter.

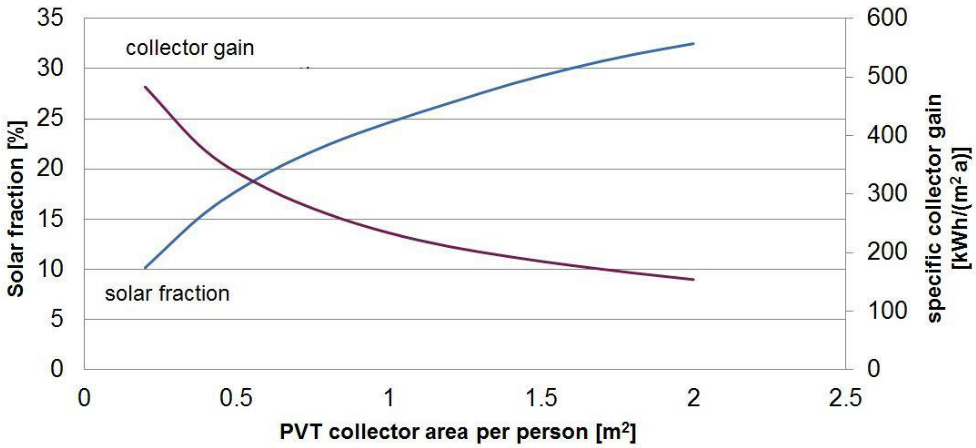

Fig. 2. Results of simulation calculations show that the a PVT-collector area of about 0.5 to 1 m^2 should be chosen for a DHW pre-heating system under the meteorological conditions of Rapperswil. These can be considered as representative for Central Europe (1100 kWh global irradiation on a horizontal surface, yearly mean ambient temperature about 10°C).

We carried out simulation calculations with the software POLYSUN from the company VELA SOLARIS [7] in order to have a basis for a decision on the question of which storage volume we should choose for a certain area of the PVT collectors that we are using.

Table 1. Simulation results for PVT pre-heating systems with the PVT collectors used in the demonstration system

PVT collector area per person	thermal output of PVT	electrical gain of PVT	increase of electrical gain compared to PV
0.5 m^2/person	330 kWh/(m^2 a)	150 kWh/(m^2 a)	+4%
1.0 m^2/person	230 kWh/(m^2 a)	150 kWh/(m^2 a)	+4%

The simulation results are shown in Figure 2 and Table 1. In summary, the conclusion is that if an area of about 0.5 to 1 m^2 per person is installed for a DHW pre-heating system (with the PVT collectors used in our investigation) a yearly thermal gain of about 330 to 230 kWh/m^2 is expected. The yearly electrical gain is about 150 kWh/m^2 which is about 4% more than the gain of PV-alone module.

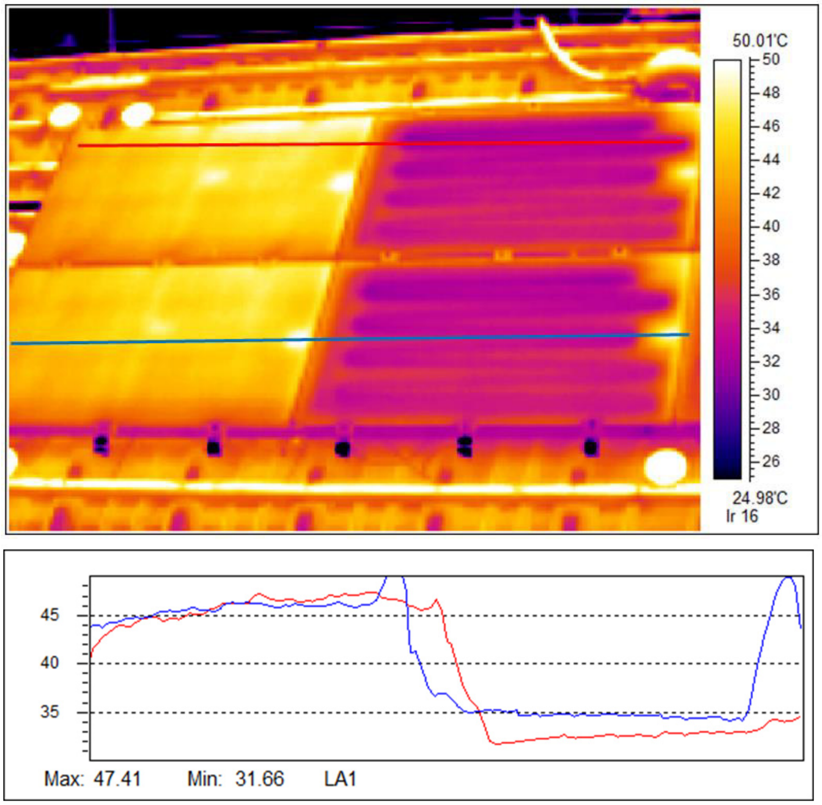

Fig. 3. Above: IR image of the left half of the installation field. The two PV panels on the left are hotter than the PVT-collectors on the right. The temperatures along the blue and the red line are given in the graph below (red curve for red line and blue curve for blue line). The highest temperatures occur at the spots were the junction boxes are placed (see for example the maximum of the blue curve).

This increase is due to the cooling effect of the PV cells by the fluid of the solar collector loop which is operated at lower temperatures as the temperatures of the PV modules cooled by natural convection. Figure 3 shows IR-images of the two PV panels (left) and two PVT-collectors (right) in order to demonstrate this effect. It can also be demonstrated clearly with figures 4 and 5. Figure 4 shows the measured electrical efficiency (on the DC side) plotted against the measured module temperatures. Each module and collector is equipped with a PT-100 temperature sensor placed on the rear side of the module/collector, approximately in the middle of the module and behind a solar cell. Our measurement campaign on the system in operation started in March 2013. One-minute mean values are monitored. We will carry out the measurements for a complete year.

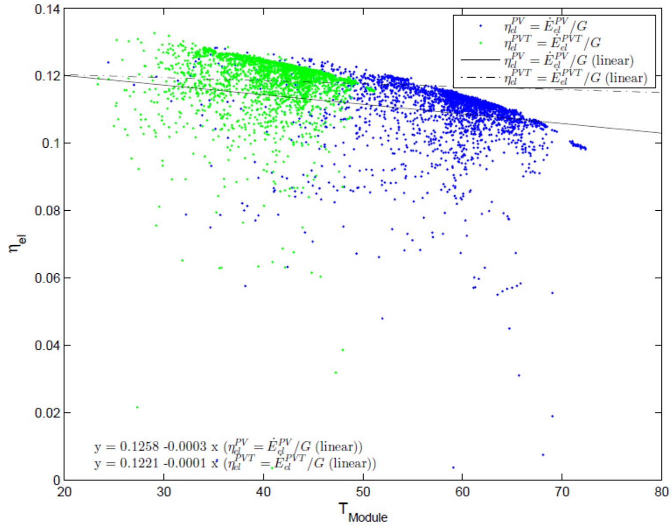

Fig. 4. Measured electrical efficiencies (DC) of PV modules (blue) and PVT collectors (green) plotted against the measured temperatures of the PV modules and PVT collectors respectively.

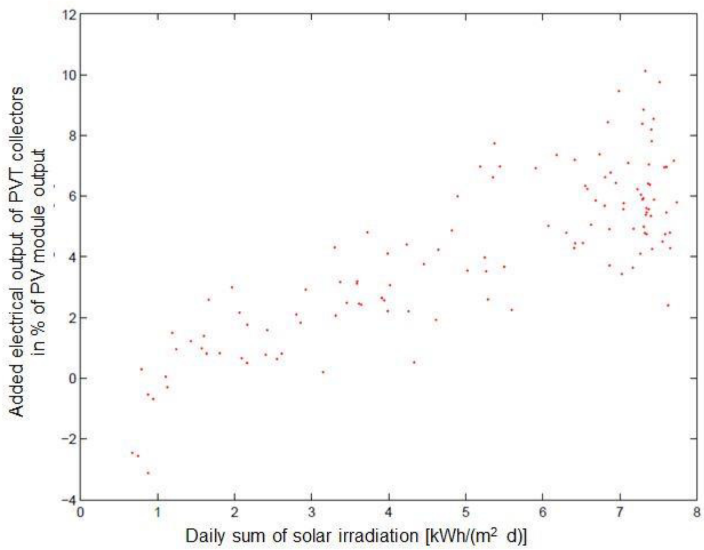

Fig. 5. Daily additional electric output of PVT collectors in percentage of PV output plotted against daily sum of solar irradiation.

Figure 5 shows a plot of the daily additional electric output of the PVT collectors as a percentage of the PV modules' output plotted against the daily sum of solar irradiation. It is likely that after a complete year our measurement result will be near to the respective value of 4% which we determined in the simulation calculations, see Table 1.

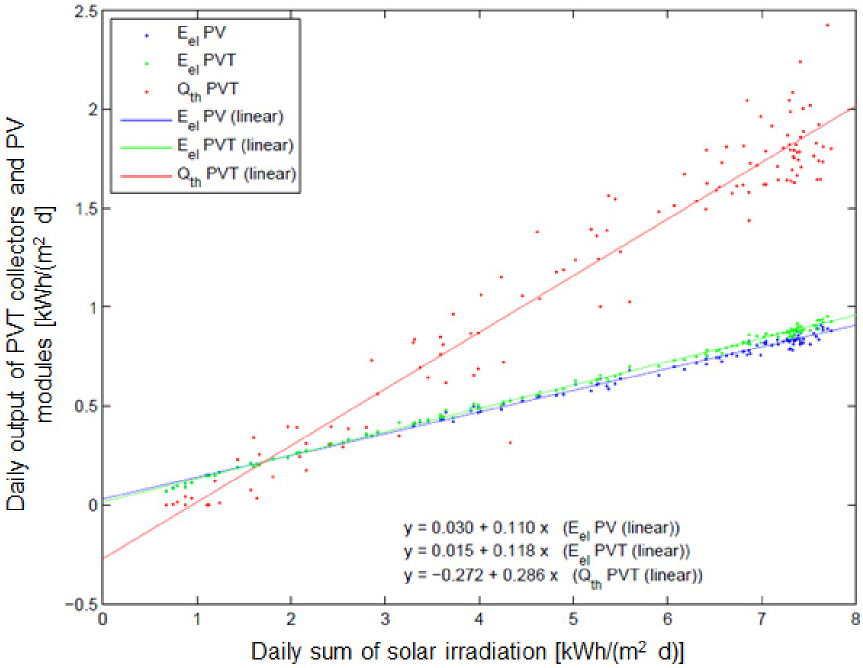

Fig. 6. Daily output of thermal energy (red dots) and electrical energy (green dots) of the PVT collectors and electrical output of the PV modules (blue dots). The parameters of the respective regression lines are given as well.

Finally, Figure 6 gives a summary of the area-specific thermal and electrical daily gains of the PV-modules and the PVT collectors which we could measure up to now.

3. Conclusions

We set up a PVT demonstration system for pre-heating of domestic hot water on the test field of SPF, Institute for Solar Technology. The system is dimensioned in such a way that the results are especially relevant for the performance of large uncovered PVT-systems for example on the roofs of multi-family houses. Our simulation results as well as the measurements carried out so far show that DHW pre-heating systems are very promising for the application of uncovered PVT collectors. The complete results will be published in due time.

Acknowledgements

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References

[1] Zondag, H.A., de Vries, D.W., van Helden, W.G.J., van Zolingen, R.J.C., van Steenhoven, A.A., 2003. The yield of different combined PV–thermal collector designs. Solar Energy 74, 253–269.
[2] Rockendorf, G., Sillmann, R., Podlowski, L., Litzenburger, B., 1999. PV hybrid and thermoelectric collectors. Solar Energy 67, 227–237.
[3] Dupeyrat, Ménézo, Rommel. Henning, Efficient single glazed flat plate photovoltaic–thermal hybrid collector for domestic hot water system, Solar Energy 85 (2011) 1457–1468
[4] Betram, Stegmann Knudmüller, Rosinski, Wärmepumpensysteme mit unabgedeckten photovoltaisch-thermischen Kollektoren, Tagungsband 21. Symposium Thermische Solarenergie, Bad Staffelstein, OTTI, 2011
[5] http://pvsystems.meyerburger.com/produkte/hybrid/.
[6] http://pvsystems.meyerburger.com/produkte/solarmodule/black/.
[7] http://www.velasolaris.com/